The Effectiveness Of A Halibut Excluder Device And Consideration Of Tradeoffs In Its Application.

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Abstract

Though the commercial value per pound of Pacific halibut (Hippoglossus stenolepis) is greater than that of most target species in trawl fisheries off Alaska, halibut retention is prohibited for trawlers and individual groundfish target trawl fisheries are subject to closure if they attain either their seasonal or annual limit of allowed halibut bycatch mortality. Although all groundfish fisheries catch considerable amounts of halibut as bycatch, only longline fishermen holding quota share in the individual fishing quota (IFQ) program are allowed to retain halibut in the federally managed fisheries off Alaska. To avoid catching halibut, trawl fishermen voluntarily developed a rigid grate system and escape panel which are installed ahead of the trawl "codend". The bycatch reduction device was then formally tested by an industry trade association in conjunction with a National Marine Fisheries Service (NMFS) fishing gear researcher under an Experimental Fishing Permit in 1998. Results from the experiment showed the device excluded 94% of the halibut while only releasing 38% of the target flatfish. Linear simulations of the fishery were developed to estimate the potential benefit of the grate. Results indicated that fleet-wide use of the grate would result in a 171% increase in the duration of the fishery, a 61% increase in target flatfish catch, and a 71% reduction in overall halibut bycatch. Other simulations demonstrated a high incentive for individual noncompliance. Factors affecting incentives for voluntary or regulatory use of bycatch reduction devices are explored in detail within the context of the highly regulated flatfish fisheries under federal management off Alaska.

Keywords – bycatch, trawl, grate, incentive, flatfish, Pacific halibut

1. INTRODUCTION

Diverse modifications have been made to fishing gears to alleviate a range of incidental catch problems collectively referred to as "bycatch". Some examples include changes in the size and orientation of trawl meshes to avoid capturing undersized fish (MacLennan 1992), grates to release fish from trawls targeting shrimp (Jones 1993), and turtle excluder devices (TEDs) to promote the egress of sea turtles from shrimp trawls (Watson et al., 1986). Bycatch reduction devices (BRDs) have also been used in non-trawl gears, such as portals in crab traps to allow escapement of non-target crab species, as well as female, or juvenile target species (Stevens, 1995).

In most cases, the use of bycatch reduction devices has come about through regulation. For instance, turtle excluders and "finfish" excluders in shrimp trawls have been implemented through regulations in response to high profile bycatch management issues (Harrington and Vendetti, 1995, Tucker et al. 1997).

Although most often brought about by regulation, it is reasonable to expect that BRDs could be adopted voluntarily, even in "open access" fisheries. This is because a reduction in catch of non-target species could increase efficiency in some cases. For instance, where unwanted bycatch species are of low value, retention of the bycatch species is prohibited, or even where retention of low-valued species is required, there should be incentive for fishermen to avoid incidental catches.

While reduction in bycatch has become a major goal of fishery management and, in some cases, the public in general, the somewhat conflicting incentives for reducing bycatch in commercial fisheries are seldom fully explored. Often, fishery managers and members of the public that follow fisheries issues likely view the bycatch impasse in simplified terms, ignoring counterincentives to the development and use of bycatch reduction techniques. Our paper uncovers several of the complexities surrounding this much-touted problem.

Often overlooked in the most simplistic depictions of the bycatch issue is the central limitation or "cost" associated with using BRDs to reduce bycatch, the reduction in target catch rates incurred from the escapement of target fish (Bublitz, 1996). The fact that such losses can be considerable at least partially explains the commercial fishing industry's traditional resistance to regulatory or voluntarily use of BRDs (Gauvin and Rose, 1997, 1998). In the extreme, BRDs may result in additional problems such as a reduction in product quality with longer towing or gear soak time, higher operating costs, or reduction in harvesting efficiency if gear handling or maintenance is problematic with the device.

Most fisheries in the United States are managed by "open access", a fishery management term referring to the situation where fishermen compete against each other for as large a share of the harvest as possible. The lack of assigned rights to a given amount of fish for a specific vessel creates a "race for fish". The end result can be excess capitalization in the harvesting sector and related problems described rather thoroughly in the literature pertaining to fisheries economics (e.g. Anderson, 1997; Neyer et al, 1989).

The lack of individual allocations of fish may also discourage the voluntary use of bycatch reduction devices because lower target catch rates can mean lower earnings (Gauvin and Rose, 1998). Therefore, one cannot ignore the issue that even where potential aggregate benefits of BRDs are large, getting fishermen to use these devices may be problematic. Experience with regulatory approaches to BRD use has shown that is does not guarantee widespread use unless resources are available to ensure compliance (Tucker et al., 1997).

This paper evaluates the voluntary development and preliminary use of a BRD to reduce incidental catch of halibut (Hippoglossus stenolepis) in flatfish fisheries in the Gulf of Alaska and Bering Sea. The case described involves voluntary use of a fairly complex set of rigid grates affixed to the webbing in the intermediate portion of a trawl net.

To investigate potential benefits available from the excluder, we first describe the complex management of the Alaskan flatfish fisheries. This elucidates incentives for voluntary or regulatory adoption of BRDs in the fishery and demonstrates some inherent obstacles. Next, performance of the excluder is described as it was measured in a field test conducted jointly by an industry trade association and a gear research scientist at the National Marine Fisheries Service (NMFS). A reliable analysis of the excluder's performance is critical to determine the economic tradeoffs of using the device.

Finally, a linear model is used to extrapolate the benefits of fleet-wide use of the excluder. To illustrate the potential for inequitable outcomes and "free rider" effects, fishery performance is extrapolated under scenarios where adoption of the device is not universal. Extrapolations illustrate that the potential for an increase in gross economic benefit in the flatfish fishery and to the public are limited by a host of confounding and countermining incentives present in the fishery management system.

1.1 Management of Flatfish Fisheries off Alaska

Commercial harvest of flatfish in federal waters off Alaska is governed by annual total allowable catch (TACs) limits for target species and associated secondary species and species groups. These TACs are managed on a fleet-aggregate basis counting all catch (retained or discarded).

Bering Sea flatfish are primarily harvested on vessels required to have NMFS-trained observers on board whenever fishing occurs. The NMFS Alaska Region Observer Program does not directly track the percentage of catch occurring from observed hauls, but a minimum estimate of that catch in 1999 was 72% (Andy Smoker, NMFS Alaska Region, personal communication).

	Bering Sea						**Gulf of Alaska**				
	Yellowfin sole	**Greenland turbot**	**Arrowtooth flounder**	**Rock sole**	**Flathead sole**	**Other flatfish**	**Deep-water flatfish**	**Rex sole**	**Flathead sole**	**Shallow-water flatfish**	**Arrowtooth flounder**
1997											
ABC	233,000	12,350	108,000	296,000	101,000	97,500	7,170	9,150	26,110	43,150	197,840
TAC	230,000	9,000	20,760	97,185	43,500	50,750	7,170	9,150	9,040	18,630	35,000
Catch	166,684	7,666	9,651	67,520	20,272	22,131	3,622	3,265	2,456	7,689	16,408
% of TAC	72%	85%	46%	69%	47%	44%	51%	36%	27%	41%	47%
% of ABC	72%	62%	9%	23%	20%	23%	51%	36%	9%	18%	8%
1998											
ABC	220,000	15,000	147,000	312,000	132,000	164,000	7,170	9,150	26,110	43,150	208,340
TAC	220,000	15,000	16,000	100,000	100,000	89,434	7,170	9,150	9,040	18,630	35,000
Catch	95,036	8,856	14,930	33,454	24,228	15,137	2,472	2,671	1,747	3,540	13,063
% of TAC	43%	59%	93%	33%	24%	17%	34%	29%	19%	19%	37%
% of ABC	43%	59%	10%	11%	18%	9%	34%	29%	7%	8%	6%
1999											
ABC	212,000	14,200	140,000	309,000	77,300	154,000	6,050	9,150	26,110	43,150	217,110
TAC	207,980	9,000	134,354	120,000	77,300	154,000	6,050	9,150	9,040	18,770	35,000
Catch	67,365	5,633	10,566	40,514	17,825	15,172	2,285	3,057	891	2,545	16,072
% of TAC	32%	63%	8%	34%	23%	10%	38%	33%	10%	14%	46%
% of ABC	32%	40%	8%	13%	23%	10%	38%	33%	3%	6%	7%

Table 1: Percent of the TAC and ABC that was actually caught.

Most fishing for flatfish species in the Bering Sea occurs on vessels that conduct primary processing on board, although around 10% of flatfish harvested in recent years in the Bering Sea has been caught by catcher vessels delivering unprocessed catches to shoreside processing plants (NMFS Alaska Region Bulletin Board). The percentage of the total flatfish delivered to shoreside processors in the Gulf of Alaska is somewhat greater than in the Bering Sea. For instance, in 1999, approximately 50% of catches of all flatfish species combined were delivered to shoreside processors (NMFS Alaska Region Bulletin Board).

Trawl vessels targeting flatfish for delivery to shoreside processors are generally smaller than at-sea processing vessels, with virtually all vessels falling in the 60 to 120 feet category, thereby requiring them to carry observers for 30% of their fishing time. In the Gulf of Alaska, an estimated 31% of the catch comes from hauls where NMFS trained observers estimated total catch and species composition (Andy Smoker, NMFS Alaska Region, personal communication).

Stock abundance levels for major flatfish species and species groups are determined through annual stock assessments conducted by the Alaska Fisheries Science Center. These assessments employ both fishery-independent and fishery-dependent data and surveys (Bering Sea and Gulf of Alaska Stock Assessment and Fishery Evaluation Reports). At present, virtually all flatfish populations in the Bering Sea and Gulf of Alaska are deemed to be at high and stable levels of abundance (North Pacific Fishery Management Council, 1999).

To provide an example of the magnitude of catches in Alaskan flatfish fisheries, annual TACs for yellowfin sole, rocksole, and flathead sole were 207,980 MT, 120,000 metric tons (MT) and 77,300 MT respectively for 1999 (Table 1). Actual harvests for that year, however, amounted to only 32%, 34%, and 23% respectively of the TACs (Table 1). In addition, flatfish TACs are often set at a fraction of the acceptable biological catch or allowable fishing level, referred to as ABC (Table 1). The full TACs are not harvested primarily due to premature attainment of prohibited species bycatch limits. Approximately the same proportional under-harvest occurs for flatfish fisheries in the Gulf of Alaska although the TACs and catches in the Gulf of Alaska are considerably lower (Table 1).

A relatively modest fraction of TACs for major flatfish species has historically been harvested since the fishery was "Americanized" in the late 1980s and without fail, this outcome has been due to premature attainment of bycatch caps for halibut and other prohibited species (Witherell and Pautzke 1997). Prohibited species must be handled to minimize injury and returned to the water as soon as possible. Retention and sale of crab species and halibut is reserved for longline gear (halibut) and pots gear (crab) (Witherell and Pautzke 1997).

The prohibited species caps for halibut are managed on a weight of halibut mortality basis. Mortality rates for halibut, which typically range from 55% to 80% depending on target fishery, are assigned on a fleet-wide basis according to the prior year's estimated overall mortality rate as calculated by NMFS fishery observers.

Bycatches of all prohibited species are managed by fleet-wide caps that are allocated between fishing targets and often apportioned seasonally. Seasonal allocations are based on industry recommendations which are designed to ensure that fishing effort is spread out over the year and to take advantage of seasonal opportunities for fishing with reduced halibut and crab bycatch (Witherell and Pautzke 1997).

To illustrate the magnitude of the constraints on flatfish fisheries, consider that the annual halibut mortality cap available in 1998 for fishing the 220,000 MT yellowfin sole TAC was 930 MT (NMFS, 1998). To prevent a premature closure because of halibut bycatch, the average bycatch rate of halibut per ton of yellowfin sole would have to be less than five kilograms, a rate which amounts to approximately one-half of one percent halibut in the yellowfin sole catch.

Given that the estimated biomass of halibut in the Bering Sea is approximately equal to the estimated population size of yellowfin sole in the same area, one can see that the bycatch cap represents a formidable obstacle for full development of the yellowfin sole fishery (Witherell, et al., in press). In actuality, halibut bycatch rates have averaged around 10 kg per ton of yellowfin sole catch (1.0%) over the 1997-1999 period, thus explaining the shortfall in the potential attainment of the yellowfin sole TAC (NMFS Alaska Region Bulletin Board).

1.2 Economic and Management Incentives

Halibut caps are divided into seasonal sub-caps for the stated purpose of distributing fishing opportunities for different users of the resource and to take advantage of seasonal opportunities for fishing when bycatch rates are lower (NMFS, 1998). The unintended effect of seasonal apportionment of halibut and crab bycatch limits for flatfish fisheries, however, is a series of "derbies" for fish over the course of the year, predicated on attainment of the bycatch limits instead of the more common competitive fishery for the total allowable catch. (Gauvin et al. 1995).

The insidious effects of managing prohibited species caps governing fisheries in the aggregate has not been widely recognized because few fisheries in the United States are governed by such binding bycatch limitations or such high levels of observer coverage (Gauvin et al. 1995).

Avoiding PSC imposes costs for fishermen because catch rates for target species can be relatively high were halibut or crab are concentrated. This may be due to natural food availability attracting both target flatfish species and halibut, or due to a "chumming" effect from discards of offal from at-sea processing. The incentive problems that result in common property resources are, of course, that costs of bycatch avoidance are individual and immediate, while potential benefits would be distributed to all fishermen, even those who did not incur the avoidance costs. This is, of course, another version of the well-described paradigm in the literature on common property aspects of natural resources management.

In addition, managers of the flatfish fisheries off Alaska appear to recognize that fishermen making efforts to minimize bycatch of prohibited species are, in effect, penalized by those who do not (Reports of the Vessel Bycatch Account (VBA) Committee to the NPFMC, 1995-1998). Despite acknowledgement of the limitations and "distributional" effects of bycatch management under open access, a rights-based incentive program has not yet been developed for the fishery due to implementation and political challenges (VBA reports to the NPFMC).

1.3 Voluntary Development and use of Bycatch Reduction Methods

To catch more of the available target fishing quotas in flatfish fisheries, flatfish fishermen off Alaska have organized voluntary "peer pressure" bycatch avoidance programs for their fisheries (Gauvin et al. 1995). The flatfish fleet's voluntary bycatch "hotspot" avoidance program called "Sea State", involves sharing observer data to calculate vessel-specific bycatch rates that are transmitted back to participants as charts identifying areas with high bycatch rates. The Sea State program has resulted in some dramatic reductions of crab and halibut bycatch rates on a fleet-wide basis, but has also experienced unequal sharing of bycatch avoidance costs with different individual levels of adherence to the rules of the program (Gauvin et al. 1995).

2. THE ROLE OF A HALIBUT EXCLUDER

Due to the shortcomings of voluntary bycatch "hotspot" area avoidance programs and entrenched obstacles to the creation of a viable system to allocate individual bycatch rights, the North Pacific flatfish industry has endeavored to develop gear modifications to increase yields from the available flatfish resource, per available amounts of bycatch (Gauvin and Rose, 1998).

The industry's application for a NMFS-approved Experimental Fishing Permit (EFP) to test a halibut excluder device states that trawler captains had been developing designs for halibut excluders independently before the formal test in 1998. (Gauvin and Rose, 1998). To remedy the problems of *ad hoc* development, a trade association for the flatfish industry applied for and was awarded an experimental fishing permit by the National Marine Fishery Service in 1998 to conduct a systematic field test of a halibut excluder (NMFS Alaska Region EFP 98-01). The stated objective of the experiment was systematic measurement of the excluder's ability to reduce halibut bycatch and its effects on target catch rates.

The principle variables of interest for the test were the effects of the excluder on halibut bycatch rates and the simultaneous effects on catch rates for target species. An additional objective of the field work was to estimate the effects of the device on the size composition of the catch. Effect on size of target fish was of interest because price premiums are sometimes paid for larger-sized flatfish (Gauvin and Rose, 1998).

2.1 Findings of the Field Test

The halibut excluder selected for testing consisted of a circular, rigid, grate with 6-inch square openings over its entire surface. The grate was mounted in the trawl intermediate and an auxiliary grate, called the "deflector", was installed ahead of the opening above the main grate to prevent fish from swimming directly aft. A report to the North Pacific Fishery Management Council provides a detailed description of the design and placement of the device (Gauvin and Rose, 1998; also Rose and Gauvin, in Prep).

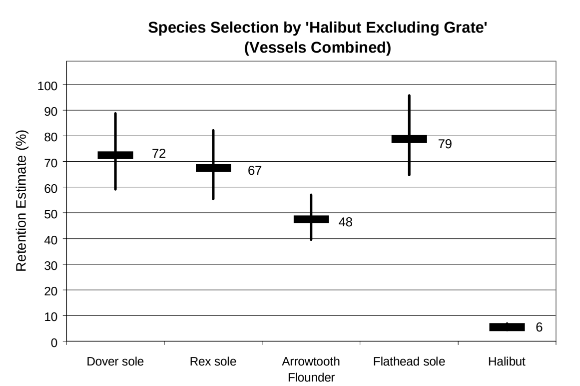

Figure 1: Percent of species retained by a trawl equipped with a halibut excluder.

The field test was conducted on two vessels in the Gulf of Alaska deep water flatfish fishery because halibut and deep water flatfish species are concentrated in the same areas and exclusion of halibut could dramatically increase yield of target species. The experimental design for the EFP involved randomly alternating experimental and control gears to create pairs of tows (experimental blocks) conducted under similar conditions. Blocking of the data attempted to eliminate variations in catch between areas, days, times of day, and between vessels from the analysis (Gauvin and Rose, 1998).

The net rigged with the excluder retained only 6% of the halibut, while keeping 62% of the aggregated deepwater flatfish species. The retention rates for the individual deepwater flatfish species varied from 48% for arrowtooth flounder to 79% for flathead sole. Dover and rex sole, primary targets of the deep water fishery, were retained at 72% and 67% respectively.

3. GENERALIZING THE RESULTS TO ESTIMATE POTENTIAL BENEFITS

Two types of benefits are potentially available from widespread use of the halibut excluder in flatfish fisheries. Increased harvest and revenues (net of costs) could increase economic performance from fishing with associated increases in producer and consumer benefits from a resource that is currently underutilized due to bycatch constraints. In addition, reduction in halibut bycatch could increase the quantity of fish available to that directed fishery. Currently, bycatch from trawl and other non-target fisheries is deducted before determining harvest levels for the directed halibut fishery. Assuming demand exists for additional halibut and flatfish, widespread use of the excluder could create a veritable "win/win" outcome for flatfish and halibut fishermen.

Making the assumption that results of the field test are applicable to the regular deep water flatfish fishery in the Gulf of Alaska, a linear programming model was developed to provide a cursory assessment of the magnitude of potential increases in harvest from the flatfish fishery and resulting benefits to the public. Further, results of that model were used to provide a rough assessment of increased benefits to halibut fishermen and the public, under a scenario of reductions in halibut bycatch accrue to the directed fishery for halibut.

The model used for the extrapolations greatly simplifies fishing performance and economic variables affecting revenues to participants in the fishery. The original intent of the extrapolations was to estimate potential for revenue increases as a result of an extended deepwater flatfish fishery and the magnitude of possible halibut bycatch savings. Neither gross or net revenue changes could be estimated, however, because the effects of the excluder on the size composition of the catch of target species could not be reliably determined from the experiment. Given that apparently large price premiums are paid for larger fish, (as high as 160% of the price for fish in the "medium" size category), a realistic conversion to revenue effects was not possible (Gauvin and Rose, 1998).

Data on variable cost structures in the fishery were also not available and hence no attempt was made to quantitatively estimate vessel level or aggregate net revenue changes. For this reason, the focus of the extrapolations was limited to catch and bycatch differences and a general description of the direction and magnitude of potential gross and net revenue effects.

	Catch in metric tons							
	Arrowtooth Flounder	**Dover sole**	**Flathead sole**	**Rex sole**	**Total Deep Water Flatfish**	**Black Cod (Sablefish)**	**Thornyhead**	**Halibut**
Catch in April 1998								
Total catch for April 1-21 1998	3,496	1,868	358	1,190	6,912	255	219	270
Catch/day (Total/ 21 days)	166.48	88.95	17.05	56.67	329	12.14	10.43	12.86
Projected target catch with excluder								
Estimated retention rate with excluder[1]	0.48	0.72	0.79	0.67		0.58	0.78	
Estimated catch/day with excluder	79.91	64.05	13.47	37.97	195	7.04	8.13	
Projected Halibut catch with excluder								
Catch/day[2]								2.20
Estimated halibut mortality/day[3]								1.36
Deep water flatfish TAC or Cap[4]	25,000	3,690	5,000	5,490	39,180	1,264	710	270
# of days to reach any TAC or Cap	57	57	57	57	57	57	57	57
Groundfish left in TAC/ Cap	19,166	$\boxed{26}$	3,871	2,738	25,802	852	236	115
Total catch when TAC is reached	4,555	3,651	768	2,164	11,137	401	464	
Halibut Mortality when TAC is reached								78
Difference in catch from April 98 fishery	**1,058.8**	**1,782.6**	**409.7**	**974.1**	**4,225**	**146.4**	**244.7**	**(192.3)**

[1] See Figure 2

[2] Estimated from experimental tows, .01 MT halibut/ MT deep water flatfish

[3] Assumes mortality rate of 62%

[4] Uses 1998 Final Specifications

$\boxed{}$ = Model convergence

Table 2: Simulation of the Gulf of Alaska deepwater flatfish fishery with full use of a halibut excluder

3.1 Estimated Catch if all Vessels Used Excluders (Extrapolation 1)

The amount of target catch taken during the 1998 April deep water flatfish opening was acquired from NMFS Alaska Region Electronic :Bulletin Board data (NMFS Alaska Region website: www.fakr.noaa.gov). In 1998, the April deep water flatfish season ran from April 1st to the 21st. The total catch was divided by 21 days to estimate the average catch per day for the model.

Estimated daily catch rates in the fishery were adjusted to project what the rates would have been if every boat used the halibut excluder tested in the fishing permit. This was done by multiplying the retention rates determined in the experimental fishery for each deep-water species. To determine the daily catch of halibut, the rate of halibut per metric ton of deep-water flatfish for the experimental tows using the excluder was applied to the projected amount of flatfish caught per day in the extrapolated fishery. Halibut catch rates per ton of deep water flatfish were converted to halibut mortality by applying the appropriate official NMFS/International Pacific Halibut Commission mortality rate of 62% assigned for the deepwater flatfish fishery in 1998 to catch rates.

The simulation of the fishery with all vessels using the excluder was modeled using the new catch rates for target species and halibut as per the results of the experiment. Constraints for the model were the annual target and halibut caps for the 1998 fishery in the Central Gulf of Alaska statistical reporting area. For every day of the fishery, (time units for the model are days), catch was accumulated for each species until this simple linear model converged on the first constraint.

The results of the first extrapolation (Table 2) point out that a great deal of additional catch in the fishery can be achieved with the lower halibut bycatch rates available from the excluder. Where the 1998 fishery lasted 21 days in 1998 and caught 329 metric tons of deepwater flatfish per day (on average) for a total catch of 6,912 metric tons, the estimated duration of the fishery with all vessels using the excluder is 57 days. Accounting for the percentage loss of target catch and the extended duration of the fishery, the estimated total catch of deep water flatfish is 11,137 metric tons, which amounts to a 61% gain in catch compared to what actually occurred in 1998. Note that the projected duration of the fishery more than doubles, but total catch is not increased to the same proportion.

Under the scenario described in this extrapolation, the fishery attains its total allowable catch limit of Dover sole (one of the deep-water flatfish species), instead of closing due to attainment of the halibut cap. It is important to recognize that all individual species or species groups are potential constraints under the reduced halibut catch rate that extends the fishery in the simulation. As will be apparent below, the set of constraints that arise with the circumvention of the halibut bycatch constraint, as afforded by the use of the excluder, is large. Unexpected outcomes are encountered as the model allows the fishery to go where it has never ventured.

Reduction in halibut bycatch estimated from the use of the excluder by the fleet also results in savings estimated at 192 metric tons of halibut (71% of the 270 metric tons taken in 1998). With the lower halibut catch rates, halibut bycatch is no longer a binding constraint for the deep water flatfish fishery. This is an important result given that the fishery has closed for halibut cap attainment every year since the halibut caps were set.

3.2 Setting Reserves in TAC to Allow for Later

	Catch in metric tons							
	Arrowtooth Flounder	**Dover sole**	**Flathead sole**	**Rex sole**	**Total Deep Water Flatfish**	**Black Cod (Sablefish)**	**Thornyhead**	**Halibut**
Catch in April 1998								
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Estimated halibut mortality/day[3]								1.36
Deep water flatfish TAC or Cap[4]	25,000	3,690	5,000	5,490	39,180	1,264	710	270
# of days to reach any TAC or Cap	49	49	49	49	49	49	49	49
Amount needed for July fishery	3,376	391	356	362	4,485	848	294	
Groundfish left in TAC/ Cap[5]	16,429	148	3,623	2,680	22,880	60	7	126
Total catch when TAC is reached	3,916	3,138	660	1,860	9,574	345	399	
Halibut Mortality when TAC is reached								67
Difference in catch from April 98 fishery	**419.5**	**1,270.2**	**301.9**	**670.4**	**2,662**	**90.1**	**179.6**	**(203.2)**

[1] See Figure 2
[2] Estimated from experimental tows, .01 MT halibut/ MT deep water flatfish
[3] Assumes mortality rate of 62%
[4] Uses 1998 Final Specifications
[5] With amount needed for the July fishery deducted from the TAC.

□ = Model convergence

Table 3: Simulation of the fishery with full use of a halibut excluder and a set-aside of thornyhead catch for later

Fisheries (Extrapolation 2)

In the first scenario, the model converged on the Dover sole TAC constraint. The longer fishery also resulted in larger catches of thornyhead rockfish (Sebatstolobus sp.), leaving only 236 MT of thornyhead quota. The quantity of thornyhead rockfish taken in the July 1998 Pacific ocean perch (POP) fishery (Sebastes alutus) was 294 MT. This remaining balance of thornyhead would be insufficient to allow the full extent of the July POP fishery to occur and thus closing the fishery prematurely. In essence, the first extrapolation amounts to a scenario that is politically unacceptable because the deep water fishery would not be allowed to foreclose on other Gulf of Alaska fisheries. Therefore, a second extrapolation arose out of an unanticipated potential consequence of liberating the deep-water fishery from its normal halibut bycatch constraint.

The deepwater flatfish fishery catches very little POP and if it were allowed to catch the thornyhead rockfish needed to carry out the July POP fishery, then over 10,000 MT of Pacific ocean perch and northern rockfish, with a first wholesale value of approximately $9.0 million would be forfeited (NMFS, 1998 (Thornyhead and Shortraker rockfish MRB analysis)). Because the July POP provides substantial revenue to a somewhat different set of fisheries, it is unlikely that managers would allow the deepwater flatfish fishery to preempt POP fishing. Thus, to explore a scenario that avoided the situation of foreclosing on the POP fishery, a second extrapolation was made to evaluate the effects of setting reserves so as not to restrict the July POP fishery (Table 3).

The second extrapolation constrained flatfish, thornyhead rockfish, and sablefish catches so that sufficient quantities were reserved for the full extent of the July POP fishery at 1998 levels of catch. When these additional constraints were added to the model, thornyhead rockfish became the binding constraint on the April deep water flatfish fishery and the model converged with deep water flatfish fishing closing after 49 days instead of the 57 days that occurred in the first extrapolation (Table 2). Catch of deepwater flatfish is reduced by approximately 15% by the shortened fishery. Nevertheless, the fishery is still significantly longer than that which occurred in April of 1998.

The second extrapolation illustrates the inherent limitations to benefits from the halibut excluder by virtue of the regulatory structure of the fisheries off Alaska. With the exception of the walleye pollock fishery, groundfish fisheries off Alaska are actually multi-species fisheries. The additional selectivity of the net with the halibut bycatch excluder produces no gains in selectivity in rockfish catches. Perhaps there is a different BRD that could circumvent these limitations, but that device, if it were possible to achieve selectivity for rockfish, would also likely have an effect on target catch rate.

It is perhaps tempting to conclude that deep water flatfish fishermen merely need to compensate the July POP fishermen for their loss of thornyhead rockfish catches. But that actually overlooks the intricacies of the management setting. Although not a prohibited species for the POP fishery, thornyhead is a minor species that also constrains the POP fishery. The "full accountability" system of fishery management in the North Pacific, given the multi-species nature of trawl fisheries, produces what have been described in production economics as Le Chatelier effects, much as those believed to overshadow the development of an individual quota management system for Pacific coast fisheries (Squires and Kirkley, 1995).

3.3 Potential outcomes given incentives for non-compliance (Extrapolations 3 and 4)

The final extrapolations evaluate the obvious potential for "free rider" problems resulting from incentives for individual gain versus collective gain. For illustrative purposes, these projections evaluate the catch on a per boat basis if all boats except one fished with the excluder (Extrapolation 3) and if only one vessel used the device (Extrapolation 4). The incentives not to use the excluder, surreptitiously or otherwise, are clear, but the magnitude of effects of such an outcome is of interest. If the rest of the trawl fleet were using the device, a fisherman could still benefit from some additional fishing time while avoiding loss of target catch. Alternatively, if only one vessel in the fleet were using the device, then there would be very little overall reduction in halibut bycatch and the only outcome that is achieved is a disproportionate loss of fishing revenue for the vessel using the device.

To illustrate these scenarios for incomplete adoption of the excluder, catch per day from Extrapolation 2 was broken down to the average daily catch per boat based on an arbitrary number of vessels in the fleet (20). The average daily catch per vessel was the daily catch in the April 1998 fishery divided by 20. The daily catch for a vessel using the excluder was determined by applying the catch reduction rates from the experiment. The daily catch per boat using the excluder was multiplied by 19 and the daily catch for the single boat that fished without the excluder was added to determine the daily catch for the fleet. Groundfish needed for the July fishery was deducted from the quotas as in the second extrapolation.

The extrapolation with a single vessel not using the device illustrated the magnitude of incentives that could exist for individual gains over collective gains. The duration of the resulting fishery was still 49 days and the model again converged due to attainment of the thornyhead catch constraint (Table 4). The model illustrated that the boat without an excluder caught nearly twice the quantity of deep water flatfish compared to the average boat using the excluder. Even more striking was the near ten-fold difference in halibut mortality between a boat that did not and one that did use the excluder (31.5 MT of halibut compared to 3.3 MT).

The potential gains from hypothetically being "the" vessel not using the device are clearly large and likely very enticing. Given that catch in the Gulf of Alaska flatfish fisheries is observed at a lower level (recall that an estimated 30% of the catch occurs from observed hauls, see above) than occurs in the Bering Sea, the real question regarding this outcome is whether any fishermen would want to use the device if there was any possibility that even one vessel was not doing so.

In reality, the degree of observer coverage is probably not the central issue. As occurred in the development of turtle excluders for shrimp trawling, there are many avenues to meet the regulatory definition of deploying an excluder while rendering that device ineffectual or decreasing its effectiveness by subtle differences in placement and rigging (Tucker et al. 1997). Further, the NMFS-trained fishery observers are placed on fishing vessels in the federally managed fisheries of the North Pacific for the purpose of collecting biological data, not fishery enforcement (NMFS Observer Manual, 1999). Perhaps most important, observers are not gear specialists and could not be reasonably expected to determine whether an excluder was being used effectively.

	Boat with excluder	**Boat without excluder**	**Difference**
Arrowtooth	195.8	407.9	212.1
Dover sole	156.9	217.9	61.0
Flathead	33.0	41.8	8.8
Rex sole	93.0	138.8	45.8
Total deep water flatfish	**479**	**806**	**327.7**
Black Cod	17.3	29.8	12.5
Thornyhead	19.9	25.6	5.6
Halibut	3.3	31.5	28.2

Table 4: Comparison of the catch by a vessel not using a halibut excluder with those of vessels using it (from Simulation 3) (catch in metric tons).

The other end of the spectrum of incomplete adoption of the excluder is the scenario where only one vessel effectively uses the excluder. This scenario could be called the "martyr". According to our model, the martyr (maybe more appropriately referred to as "poor soul") would end up with 205 MT of target groundfish catch and the average vessel that did not use the excluder would end up with 346 MT.

Because only one vessel uses the excluder, the fishery is not even extended by a full day compared to what occurs

	(catch in metric tons)							
	Arrowtooth Flounder	**Dover sole**	**Flathead sole**	**Rex sole**	**Total Deep Water Flatfish**	**Black Cod (Sablefish)**	**Thornyhead**	**Halibut**
Catch in April 1998								
Total catch for April 1-21 1998	3,496	1,868	358	1,190	6,912	255	219	270
Catch/day (Total/ 21 days)	166.48	88.95	17.05	56.67	329	12.14	10.43	12.86
Estimated daily catch per boat[1]	8.32	4.45	0.85	2.83	16	0.61	0.52	0.64
Projected target catch with excluder								
Estimated retention rate with excluder[2]	0.48	0.72	0.79	0.67		0.58	0.78	
Estimated catch/day with excluder	79.91	64.05	13.47	37.97	195	7.04	8.13	
Estimated daily catch per boat	4.00	3.20	0.67	1.90	10	0.35	0.41	
Projected Halibut catch with excluder								
Catch/day[3]								2.20
Estimated halibut mortality/day[4]								1.36
Estimated daily catch per boat								0.07
Catch/day for fleet								
19 boats using excluder	75.91	60.84	12.79	36.07	186	6.69	7.73	1.30
1 boat w/o excluder	8.32	4.45	0.85	2.83	16	0.61	0.52	0.64
Projected catch/day for whole fleet	84.24	65.29	13.65	38.90	202	7.30	8.25	1.94
Deep water flatfish TAC or Cap[5]	25,000	3,690	5,000	5,490	39,180	1,264	710	270
# of days to reach any TAC or Cap	49	49	49	49	49	49	49	49
Amount needed for July fishery	3,376	391	356	362	4,485	848	294	
Groundfish left in TAC/ Cap[6]	16,217	87	3,614	2,634	22,552	47	$\boxed{2}$	98
Total catch when TAC is reached	4,128	3,199	669	1,906	9,902	358	404	
Halibut Mortality when TAC is reached								95
Total Catch/boat with excluder	195.8	156.9	33.0	93.0	479	17.3	19.9	3.3
Total Catch/boat without excluder	407.9	217.9	41.8	138.8	806	29.8	25.6	31.5
Difference	**212.1**	**61.0**	**8.8**	**45.8**	**327.7**	**12.5**	**5.6**	**28.2**

[1] Assumes a fleet of 20 boats in the fishery
[2] See Figure 2
[3] Estimated from experimental tows, .01 MT halibut/ MT deep water flatfish
[4] Assumes mortality rate of 62%
[5] Uses 1998 Final Specifications
[6] With amount needed for the July fishery deducted from the TAC.
$\boxed{}$ = Model convergence

Table 5: Simulation of the fishery with use of a halibut excluder by all but one vessel.

without any vessels using the excluder, so no net gains in groundfish catch are realized. This means overall halibut savings are negligible and the only notable effect of the use of the excluder is that fishermen that do not use the device catch about 1.7 times as much target catch (and 14 times as much halibut bycatch) as the fisherman who do.

3.4 Context for interpretation of the results of the extrapolations

While data availability makes it impossible to incorporate gross and net economic tradeoffs into the linear extrapolation model, the extrapolations do illustrate the magnitude of some important tradeoffs and incentives for voluntary or regulatory compliance.

The most important weakness to the extrapolations is that without data to incorporate fishing cost structures and vessel or firm-level net returns, there is no way of knowing whether the reduction in target catch rate justifies use of the excluder for any or all vessels. The extrapolations suggest that with lower halibut bycatch rates, the fishery would be dramatically extended and thus more target groundfish would be produced. The ability of fishing firms to justify fishing costs at the lower catch rates cannot be evaluated with the aggregate linear model that lacks marginal revenue and cost information.

Although there is no rigorous way to evaluate the question of economic margins with available data, some fishermen appear to be using the excluder voluntarily, suggesting that reductions in catch rate are more than compensated by additional fishing opportunities, at least in the short run. How fishermen voluntarily using the device at present are affected by disproportionate revenue and cost effects is not known. It is at least possible that through peer pressure and other means, fishermen have been able to obtain full voluntary cooperation thus far.

In evaluating the fishery yield and bycatch tradeoffs presented in the extrapolations, it is certainly tempting to suggest potential solutions outside of the "management box" affecting the fishery. For instance, it is probably more efficient to allow flatfish fishermen to purchase rights to halibut IFQ, thus theoretically allowing them to retain halibut and obviating avoidance costs associated with reducing bycatch for the trawl fisheries. It must be noted that regardless of how enticing these "outside" solutions appear to be, they are currently "unavailable" to flatfish fishery participants (VBA report).

	(Catch in Metric Tons)							
	Arrowtooth Flounder	**Dover sole**	**Flathead sole**	**Rex sole**	**Total Deep Water Flatfish**	**Black Cod (Sablefish)**	**Thornyhead**	**Halibut**
Catch in April 1998								
Total catch for April 1-21 1998	3,496.00	1,868.00	358.00	1,190.00	6,912.00	255.00	219.00	270.00
Estimated catch/day (Total/ 21 days)	166.48	88.95	17.05	56.67	329.14	12.14	10.43	12.86
Estimated daily catch per boat[1]	8.32	4.45	0.85	2.83	16.46	0.61	0.52	0.64
Catch rate using halibut excluder								
Estimated retention rate with excluder [2]	48%	72%	79%	67%		58%	78%	6%
Estimated daily catch for one boat	4.00	3.20	0.67	1.90	9.77	0.35	0.41	
Halibut catch/day[3]								0.10
Estimated halibut mortality/day[4]								
Catch/day for fleet								
19 boats not using excl00uder	158.15	84.50	16.20	53.83	312.69	11.54	9.91	12.21
1 boat with excluder	4.00	3.20	0.67	1.90	9.77	0.35	0.41	0.06
Projected catch/day for whole fleet	162.15	87.71	16.87	55.73	322.46	11.89	10.31	12.27
Deep water flatfish TAC or Cap[5]	25,000	3,690	5,000	5,490	5,490	1,264	710	270
# of days to reach any TAC or Cap	21	21	21	21	21	21	21	21
Amount needed for July fishery	3,376.00	391.00	356.00	362.00	4,485.00	848.00	294.00	
Groundfish left in TAC/ Cap [6]	16,939.90	1,444.15	3,928.76	3,369.64	25,682.44	155.36	189.41	12.23
Total catch when Halibut Cap is reached	3,405.10	1,841.85	354.24	1,170.37	6,771.56	249.65	216.59	257.77
Total catch /boat								
Total Catch/boat with excluder	83.90	67.25	14.14	39.87	205.16	7.40	8.54	1.27
Total Catch/boat without excluder	174.80	93.40	17.90	59.50	345.60	12.75	10.95	13.50
Difference	90.90	26.15	3.76	19.64	140.44	5.36	2.41	12.23

[1] Assumes a fleet of 20 boats in the fishery
[2] See Figure 1
[3] Estimated from experimental tows, .01 MT halibut/ MT deep water flatfish
[4] Assumes mortality rate of 62%
[5] Uses 1998 Final Specifications
[6] With amount needed for the July fishery deducted from the TAC.

= Denotes model convergence

Table 6: Simulation of a fishery in which only one vessel uses a Halibut Excluder

To frame the discussion of what the extrapolations reveal about potential for increased benefits with expanded use of the halibut excluder, the following baseline assumptions are made:

1. That halibut is valuable, thus avoiding taking it as bycatch creates benefits to the halibut fishery and society.

2. The system that makes halibut a prohibited species creates inherent costs on fishermen and society because avoiding halibut bycatch is not without individual and public costs. Managers have opted to build a management system around halibut, however, and we assume that the only potential for private and public sector benefit is from avoiding halibut bycatch at minimal cost to the flatfish industry such that more flatfish resource can be utilized.

Given the two assumptions above, the extrapolations illustrate potential for catching more flatfish with less halibut and without affecting other groundfish fisheries. The magnitude of potential gains in groundfish catch appears fairly sizable, particularly with universal adoption of the excluder. For instance, if we assume away the problem of not having data to estimate the effect of the excluder on the average size of rex sole in the catch (i.e. no effect on average size of target catch species), some gross estimates of revenue increases can be made under the assumption of universal use of the excluder in the April rex sole fishery. These estimates are based on the increases in catch from the fishery in Table 3, the scenario of universal use of the excluder and sufficient groundfish set aside for the July POP fishery.

Assuming an average price of $1.85 per pound for rex sole (rex sole is generally produced into “frozen round” product form), standard recovery rates for head and gut flatfish and incidental rockfish catches (NMFS Regulations), and current first wholesale prices for the appropriate product forms (Laure Jansen, Talbot Associates, Inc., personal communication) we estimate that the April deep water fishery could be worth as much as an additional $5.1 million, at the first wholesale (FOB Kodiak) level if all participants used the excluder. As mentioned before, however attractive this estimated annual increase in gross revenue might seem, there is no way of knowing if it is attainable. Lacking cost data, there is no way of gauging whether boats employing the excluder would actually be operating profitably.

Potential benefit from a net reduction in halibut bycatch taken in the deep water flatfish fishery could also be considerable. According to the same extrapolation used for the estimate of gains in the deepwater flatfish fishery (Table 3), approximately 200 MT of halibut mortality would be saved while still allowing the projected annual gross revenue increase described above. Assuming this quantity of catch was transferred to the directed halibut fishery (and that there is no price effect from an increase in quantity supplied), we estimate a gross revenue increase of $1.2 million ($2.70 is the current ex vessel price as reported in Pacific Fishing, June 2000 issue).

This certainly suggests that adoption of the halibut excluder would be beneficial, particularly when one contemplates that the excluder may be workable in Bering Sea and Gulf of Alaska flatfish fisheries and where potential increases in flatfish harvest and halibut savings are much larger. Under the current management regime, however, the potential for free rider behavior and the erosion of voluntary compliance also seems probable. Some might deduce that this appears to argue for a regulatory approach to implementation of the halibut excluder. But experience in the North Pacific fisheries with gear regulation based on technical definitions and performance variables has not been positive in similar circumstances. For instance, although recommended by the North Pacific Fishery Management Council in 1994, NMFS Alaska Region has opted not to implement minimum mesh size regulations because the agency believed that field monitoring and enforcement is not practical (9/19/94 Letter from NMFS Alaska Regional Administrator Steve Pennoyer to the North Pacific Fishery Management Council explaining NMFS’ decision not to implement minimum mesh size regulations).

All of the above raises the question of whether potential gains in flatfish harvest and halibut bycatch reduction are attainable. We speculate below regarding the best approach to attainment of gains from increased selectivity in the flatfish fishery.

4. INCENTIVES FOR OPTIMIZING YIELD AND REDUCING HALIBUT BYCATCH

While most fisheries managers in the United States and around the world are wrestling with how to reverse overexploitation to rebuild stocks, all available biological indicators suggest that there is significant potential for far higher yields from flatfish fisheries in the Gulf of Alaska and Eastern Bering Sea. The fishery management system in place for these fisheries serves to reduce incentives for bycatch reduction at the level of the individual fishing firm. Further, the management system constrains the fishery to whatever biological or other catch threshold, such as prohibited species caps, that the fishery reaches first. These various constraints are adhered to regardless of the benefit/cost implications for the flatfish industry or the public. Thus the question is what course best increases economic yields from the large flatfish resource and how to best move in that direction.

While fishermen have apparently begun to use halibut excluders on a voluntary basis, it is probable that the unequal sharing of costs and benefits will result in the erosion of the willingness to do so in the longer run. Experiences with regulatory approaches to gear use and the apparent need for careful adjustment and maintenance of excluders and other BRDs does not suggest that a requirement to use excluders would necessarily achieve the desired objective of increasing yields and reducing halibut bycatch.

The alternative explored below is how to seek to make individual incentives and benefits for using the excluder more closely wedded with overall incentives. While obvious, this approach is not without its problems and political hurdles.

The body of economic literature describing rights-based solutions to commons problems in natural resource management would indicate that the best solution may be assignment of bycatch and target catches at the level of the individual vessel or fishing firm. Economists might well debate the need for assigned rights to target catch, at least at the outset, given that firm-level incentives for use of the excluder depend on incentives for increases in yields of target catch.

Under such a system, faced with an individual scarce quantity of halibut bycatch, each fisherman could be expected to seek optimal use of his available bycatch limits. One would then expect that use of the halibut excluder would occur, particularly if the excluder's effect on target catch rates was, in fact, tenable. Is such a rights-based system feasible for this fishery and would the excluder be used if such a system were in place?

One can glean a great deal of information on the possible use of individual assignments of bycatch rights from the various reports made by a committee charged to investigate the use of such a system for the fisheries in question. Starting in 1995, the North Pacific Fishery Management Council formed a committee to develop recommendations on approaches to reduce prohibited species bycatch and increase yields in fisheries constrained by prohibited species caps. The committee, which called itself the "vessel bycatch accounts", or "VBA" committee worked from 1996 through 1999 on the project and has not been reconvened since.

The VBA committee was composed of groundfish and halibut IFQ industry members as well as representatives of environmental groups (Reports of the VBA Committee 1995-1998). Their reports explore the potential use of individual quotas for bycatch species and the implementation problems that might arise from such a system, recalling that a long list of constraints affect the groundfish fisheries of the North Pacific in addition to prohibited species caps. Although the committee's ultimate recommendation is to move forward with such a system, their reports illustrate a number of problems with individual vessel or firm assignment management system for these fisheries.

One problem that permeates the deliberations is the fact that the observer sampling done in multi-species fisheries, such as flatfish, was actually designed to measure fleet-wide catch over the course of a week rather than vessel performance on a daily basis. The observer coverage resources that might be needed to allow tracking of vessel-specific performance is not actually detailed in the committee's reports because the committee eventually opted for a different avenue to remedy this problem. The committee's stated objective regarding sampling was to require no net increase in observer coverage resources.

The committee eventually recommended that prohibited species caps be pooled among sub-groups of the fleet which would be expected to monitor individual performance and enforce bycatch reduction incentives through private contracts. Such a system is actually currently in place in the pollock fishery of the North Pacific, which is managed under a system of private cooperatives as allowed under the American Fisheries Act of 1998 (AFA, 1998). Whether such a system would work in the more multi-species fisheries targeting Pacific cod and flatfish is not known.

The issue of individual rights to bycatch was apparently a controversial subject for the VBA committee. The root of the issue for some members representing the halibut IFQ and environmental groups was whether such a system would "institutionalize" bycatch of prohibited species at their current levels. The thought was that if individuals outside the IFQ fishery had some sort of entitlement to the bycatch, then it might be more difficult to reduce the prohibited species caps in the future. From the committee reports, this is the most contentious issue and probably the one that served to impede progress.

One additional issue that pervades the committee's reports is the doubt raised as to whether flatfish and other groundfish fisheries, if extended in duration by lower bycatch rates, would not usher in unanticipated negative outcomes, such as the one that is explored in the second extrapolation.

It is difficult to discern effects of unanticipated consequences based on committee reports because such occurrences are not always knowable without a trial or pilot program. The complex regulatory system for the flatfish fisheries does appear to have a high potential for such outcomes, as was seen in the extrapolations above. Perhaps set asides of catch for later fisheries would solve the problem, without sacrificing net gains in target species yields or halibut bycatch reduction.

The major advantage to a system of assigned rights might be that individuals taking steps to improve fishing practices would reap the rewards individually instead of incurring additional fishing costs while other fishermen obtain without costs the increased catches during the extended fishing seasons. In all probability, such a system might remove the race for fish, or in this case, a race to fish before the overall bycatch cap is attained. While the use of halibut excluders and other advances might complicate the management of the fishery (for instance, the potential unanticipated foreclosure of other fisheries, such as in the second extrapolation), these problems might also be more manageable under a slower-paced fishery.

With such a system in the pollock fishery, a fishery that is admittedly far less complex, the pace of fishing has slowed with the concentration of maximizing revenues through product quality instead of product volume (APA coop report to NPFMC). Fishermen in pollock cooperatives have apparently accepted the added cost of accounting for catch on a vessel by vessel basis and taken over some of the responsibility of providing additional accounting via increased observer coverage (industry pays for observer coverage in all North Pacific fisheries), hiring outside contractors, and other accounting resources.

In the end, such a system may allow for the advent of vessel-specific bycatch and possibly later target catch management for flatfish fisheries. Under such a system, fishermen might well adopt halibut excluders if the loss of revenue on a dollars per day basis is more than justified by the gains in yield from the fishery. Under such a system, fishermen might well experience a better environment for perfecting gear, such as reducing the loss of target catch for the excluder. Given the large potential for increased yields, it seems that a premium on knowledge and skill for innovation would prevail and rights in the fishery, should rights to bycatch be transferable, might well flow to those best able to innovate to reduce bycatch.

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